INSA Workshop

HEALTH OF SCIENCE IN INDIA

Analysis and Recommendations

INDIAN NATIONAL SCIENCE ACADEMY
BAHADUR SHAH ZAFAR MARG, NEW DELHI-110002

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Based on the deliberations of a Workshop held at the Indian National Science Academy, New Delhi, April 17—18, 1986

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December 1986

Printed and Published by Dr. V. C. Vora, Executive Secretary, Indian National Science Academy, Bahadur Shah Zafar Marg, New Delhi-110002 and printed at Kapoor Art Press, A38/3, Mayapuri Industrial Area, Phase 1, New Delhi-110064

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FOREWORD

The country has witnessed a phenomenal growth in the number of research laboratories as well as agencies and organizations dealing with science and technology since Independence. The nation has made a substantial investment on science and technology. This has resulted in the creation of an adequate infrastructure for research and development in a variety of areas, such as agriculture, atomic energy, space, chemical technology and biomedical sciences. A large number of institutions devoted to higher learning have also been established to produce the required manpower. Today, India has a large concentration of scientific and technical manpower. In spite of our spectacular achievements, specially in some sectors of science and technology, there seems to be a general feeling that all is not well with regard to the quality of scientific research and higher education. There appears to be a genuine need to carefully examine and analyse various aspects related to the status of science in the country. The Academy has been concerned with this entire question for some time. In the meantime, the Science Advisory Council to the Prime Minister also requested the Academy to prepare a report on the "Health of Science".

The Academy organized a Workshop on *Health of Science in India* on April 17-18, 1986, and deliberated on the following major issues: Trends in science in India since Independence; infrastructure, resources and other aspects related to the quality of science; role of motivation in achieving excellence; system of education; peer evaluation; brain drain; social and cultural factors; and recent trends in the international scene. A number of scientists presented lead papers and participated in

the discussion. A set of recommendations have emerged from the Workshop.

Professor R R Daniel, Vice President of the Academy, took the responsibility of organizing the programme and devoted considerable time and effort in preparing this report based on the proceedings of the Workshop. We owe much to Professor Daniel for his painstaking interest and invaluable help. The Academy is indebted to the various experts who contributed papers and participated in the deliberations. Thanks are extended to Professor S K Joshi, Professor H Y Mohan Ram and Professor P N Tandon, Shri A K Bose (former Executive Secretary) and Dr Alok Moitra for the efforts put in by them in the organization of the Workshop and in the preparation of this report. I thank Shri R N Sharma, former Editor of the Publications and Information Directorate, Council of Scientific and Industrial Research, New Delhi, for editing and production of the report.

I am delighted that we have a document on the Health of Science in the country. I hope it will be found stimulating and useful.

C N R Rao
President

SUMMARY

In response to critical comments made at various fora in recent years regarding the health of Indian science, the Indian National Science Academy (INSA), as the premier representative body of the Indian scientific community, at its own initiative and also on a suggestion from the Science Advisory Council to the Prime Minister, organized a two-day Workshop (April 17-18, 1986) at INSA premises with the participation of about 60 senior scientists representing different disciplines and science administrators from various sectors. Despite the realization of close interrelationship between science and technology, the deliberations at the Workshop were intentionally restricted to issues primarily related to the health of science, the main motive being to focus attention and ensure in-depth and coherent discussion.

The major objective before the Workshop was to identify the strengths and weaknesses of the existing research set-up, to analyse them and to come up with suggestions and recommendations to rectify and neutralize the obstacles and promote quality and excellence.

Before taking up major issues, it was considered prudent to identify the strengths (healthy states and trends), obvious and inherent, then examine critically and objectively the factors responsible for the present state of affairs and finally to make concrete and pragmatic recommendations for rectifying the situation in some of the areas.

Healthy States and Trends

(i) The huge body of trained scientific manpower is a major national asset.

(ii) Despite the poor average standards in teaching and training in science, a good number of high quality graduates and postgraduates in science and technology are consistently moulded and turned out in some selected institutions.

(iii) Funding agencies and peer groups are showing a keen awareness about the need for promoting qualitative improvement. Critical and objective appraisal and monitoring of activities are being done on an increasing scale than in the past.

(iv) A satisfactory level of success has been achieved in a few laboratories in fabricating sophisticated instruments through indigenous effort to aid quality research at the forefront of existing knowledge.

(v) Indian science has the rare privilege and advantage of consistent governmental assistance and organized patronage since Independence.

Factors Impeding Quality Improvement

(i) Inadequacy of physical resources (funds, infrastructure, equipment, civil works, responsive management and administration, etc.), particularly in the university and affiliated college systems.

(ii) Failure to make major inroads in the area of design and fabrication of innovative modern instruments and equipment and increasing dependence on imported sophisticated instruments and systems.

(iii) Non-optimal utilization of major equipment and instruments through the poor management practices prevalent.

(iv) Inadequate library facilities available to the students and research workers, compounded by our failure to modernize the information communication facilities to the desired extent.

(v) Failure to realize the close dependence and linkage between organization and management and excellence in science, and continued adherence to the same types of management systems and philosophies as for other fields.

(vi) Failure to develop an objective and impartial peer review tradition needed to promote excellence in science and to evolve and implement a clear-cut national policy in this respect. As a consequence, mediocrity is prospering at all levels.

(vii) Neglect of the vital dependence of excellence in scientific research on the quality of higher science education and training, especially at the graduate and postgraduate levels, and continuing with outmoded methods.

(viii) Lack of an effective system for in-service training and reorientation of teachers.

(ix) Failure to modernize syllabi, teaching methods and examination systems.

(x) Laxity in admissions to postgraduate courses with merit becoming the most prominent casualty.

(xi) Due importance not being given to merit as the sole criterion for recruiting postgraduate teaching and research staff, and continued prevalence of inbreeding in the matter of appointments, leading to erosion of standards.

(xii) Failure to limit the extent of brain drain.

(xiii) Inadequate attention being paid to certain important issues, such as:

(a) Evolving an environment conducive to creative science in the research centres and universities.

(b) Continuation of seniority and authority syndrome in research centres.

(c) Encouragement for the development of motivation among younger researchers.

(d) Continuation of beliefs of superstition, irrationality and fatalism in certain quarters.

(xiv) Influence of the prevalent national milieu characterized by the all-pervading rush to make quick money, the means having become secondary to the ends.

Suggestions and Recommendations

(i) Essential infrastructural facilities needed by researchers should be provided at the requisite level. There should be clear demarcation between the responsibilities of the parent institution concerned, UGC and the research project funding agencies. The host institution must ensure optimal and shared utilization of the available infrastructural facilities.

(ii) Provision should be made for the supply of relevant scientific literature needed by students and research workers. The specific recommendations made in this respect are as follows:

(a) To promote learning, the libraries must be expanded through increased funding.

(b) Libraries of scientific institutes and their systems must be modernized without delay.

(c) Libraries in metropolitan cities and different regions must evolve efficient systems of sharing and exchanging their resources.

(d) The UGC sponsored 'Current Awareness Service' set up at the Indian Institute of Science, Bangalore, presently geared to supply on request printouts of articles in physics free of cost should be extended to all scientific disciplines.

(e) A national information centre should be set up as early as possible.

(iii) A national policy on instrument development and fabrication should be formulated and implemented as early as possible, with focus on crossing over the line of criticality

whereby the country can start designing and fabricating all types of sophisticated instruments and equipment. Both public and private sectors of industry should be involved in this. Persons with innovative instrumentation capabilities should be given due encouragement. Their status must be considered equivalent to that of other scientists. Effective mechanisms should be evolved in respect of sharing of major instruments and equipment.

(iv) Peer review system should be enforced rigorously. Mediocre and repetitive research must be stopped.

(v) A responsive and efficient management system must be provided at all research centres.

(vi) University departments and colleges doing postgraduate teaching in science must have properly screened and pre-evaluated research programmes.

(vii) Admission to M.Sc. and Ph.D. programmes must be based on merit and motivation. Selection should be done through rigorous entrance tests.

(viii) Incentives should be provided to the selected students to motivate them to give their best.

(ix) Recruitment of postgraduate teachers should be strictly on merit basis. It should be brought home emphatically to all concerned that the dictum 'mediocrity breeds mediocrity' applies to science as well.

(x) Teaching methods should be modernized with emphasis on building up of innovative capabilities among the students. Orientation and refresher courses for teachers should be a regular component of higher education.

(xi) Effective linkages should be built between universities, national laboratories and industry.

(xii) The culture of seminars by students and staff should be encouraged and made a regular part of the educational system.

(xiii) Concrete steps should be taken to enhance the mobility of scientists, paying due attention to such matters as accommodation, financial compensation, children's education, etc.

(xiv) The problem of 'brain drain' should be studied in its totality and an effective and viable policy should be evolved for limiting it. Attention should also be paid to channellizing trained youth within the country for national development. The possibility of introducing one year's compulsory national service in a suitable form for all graduates should be examined.

(xv) Data should be collected by IITs and other concerned institutions of higher learning on a continuing basis on the young people going abroad for higher studies and training, their progress, their plans for return, etc. Our missions abroad should also gather information on scientists and engineers of Indian origin and be in close contact with them.

(xvi) Non-physical resources (in particular the work environment) should be considered as important as the physical resources. The main recommendations in this respect are:

(a) A code of conduct needs to be drawn up with the involvement of scientists, managements and funding agencies, which should include the scientist's own style of working as well as his interaction with his colleagues.

(b) Creation of an atmosphere and environment congenial for creative work should be the responsibility of all scientists, both individually and collectively.

(c) Over-emphasis on seniority and authority should be discouraged in research centres.

(d) Through discussions and seminars junior scientists should be enthused to feel that they are as much responsible for the healthy progress of research as the seniors.

(e) Joint studies involving natural and social scientists aimed at investigating the influence of socio-economic factors on the endeavours at achieving excellence in science in the Indian context should be conducted.

(xvii) All concerned with the quality of science should show full awareness about emerging international trends, so that effective strategies could be worked out to ensure that we do not lag in those fields.

(xviii) INSA should constitute an action committee to follow up these recommendations and take further steps for implementation. In this effort, the government, UGC, funding agencies, national and state academies of science, professional scientific societies and scientific institutions should be actively involved.

ABOUT THE WORKSHOP

There seems to be a widespread view in the country that in spite of spectacular achievements in fields like agriculture, atomic energy and space since Independence, the quality of science in India leaves much to be desired. Because of the intrinsic value and importance of quality and excellence in science and scientific research, many discussion meetings and seminars have been held in recent years to discuss the validity of this inference and to examine the reasons for it. This matter has been raised on many occasions in the Academy as well. Statements on this subject by individuals are generally based on personal opinions rather than on learned inferences. While scientists are in a way more knowledgeable about many of the associated facts and factors, there is likely to be a subjective element because of their deep involvement in science. Generalizations are often made on the basis of one or two isolated instances. Considering all this, it was felt that there was need for the Academy to examine the matter afresh as objectively as possible, identify our weaknesses as well as strengths, examine the possible reasons for the weaknesses and make appropriate recommendations to minimize, if not completely eliminate, the obstacles and thus promote quality and excellence. While this is an enormous task considering the complexity of the problem, it was thought that a serious beginning must be made. The Academy in the meantime received a request from the Science Advisory Council to the Prime Minister (SACP) to prepare a report on the "Health of Science in India".

In the light of the above, the Academy decided to organize a Workshop to discuss the health of science in the country. An option the Academy had was to invite a number of

distinguished and knowledgeable people to deliver lectures on the subject followed by free discussion. Another option was to study the various dimensions of the problem first, break them down into a number of reasonably well defined topics, deal with them separately to the extent possible, and then integrate and consolidate the outcome. Since discussions can easily become diffuse and subjective while dealing with a topic like this, it was decided that the second option would enable better focussing and clarity. The following classification of topics was adopted for purpose of convenience:

(i) Healthy states and trends in science in India since Independence.

(ii) Lack of resources, infrastructure, industrial base, responsive management, etc. and their impact on the quality of science.

(iii) What is the role of motivation in achieving excellence in science? Is it lacking in India, and if so, what are the reasons for it?

(iv) Is the present system of education conducive to quality science? If not, what can be done to improve the situation?

(v) Is our system of peer evaluation and science communication adequate? How can we improve it?

(vi) Brain drain—Facts, reasons and remedies.

(vii) Are there any hindrances arising from social and cultural factors?

(viii) New trends in science in the international scene and their effect in India.

Three persons were invited to write a paper on each of the above topics in order to ensure that different points were available (*see* Annexure for list of authors). At the Workshop, one person from each group was invited to make an oral presentation. Adequate time was provided for discussion at the

end of each presentation. At the end of the meeting, time was allotted for a general discussion, comments and suggestions.

The Workshop was held at the Academy premises on 17 and 18 April 1986. The first session was chaired by Professor M G K Menon, Scientific Adviser to the Prime Minister and Member, Planning Commission. Sessions on the second day were chaired by Professor C N R Rao, President, INSA and Chairman, Science Advisory Council to the Prime Minister. About 60 scientists and some science administrators and managers participated in the Workshop.

It is difficult to do full justice to the numerous facets of the subject of Health of Science in India. Each one of them would require an in-depth study in order to understand the implications meaningfully. Many useful points however emerged from the Workshop which are worthy of consideration. This brief report has been prepared to highlight the important findings, observations and recommendations of the Workshop.

The first draft of the report was sent to all the contributors and other specialists. Several useful comments were received, which have been incorporated in the final document. Annexure 1 lists the authors.

PROLOGUE

Before we proceed with the proceedings of the Workshop, it seems profitable and appropriate to set the subject under consideration in a proper perspective. It will also enable proper appreciation of the complexity of the problem and its numerous connections, which may or may not be obvious in the national and international context.

Until our Independence in 1947, scientific research was carried out in scattered centres in a sporadic manner. Such activities centred around one or more intensely motivated individuals (and patrons) and were carried out usually under difficult situations and circumstances and with limited resources. Support and encouragement from the government were rather limited and unorganized. Notwithstanding this, a few great men with tremendous dedication who took up scientific research made contributions of excellence in their chosen fields and secured international recognition for their indisputable calibre. This was also the time of the freedom movement which swept across the country generating an intense sense of national pride, fully shared by these eminent men of science too.

After Independence, there has been a vast and rapid increase in the number of scientific institutions and scientists and the tempo of research activity. Science has now become as organized and institutionalized as anywhere else in the world and our government recognizes the role of science and technology in national development. Scientific research is now carried out mainly with government funding. The number of universities competing with one another to produce more graduates and postgraduates has multiplied rapidly. Scientific profession has become another profession with many new

entrants coming in without any special motivation or urge to enquire into the subtleties of nature or discover new knowledge. While most of the advanced countries were able to strike a reasonable balance between institutional funding, university autonomy and academic excellence, this did not happen in India to the desired extent.

Another relevant factor here is the prevalent national milieu in which scientists too grow, live and work. New opportunities for economic benefit have multiplied mainly in the metropolitan centres. This has resulted in concentration of wealth in a small group of people, leaving the bulk of our population almost untouched. There is a mad rush to make quick money with little consideration about the means adopted. The value system of individuals, families and societies gives undue importance to opulent living and places a disproportionate premium on anything foreign. Going abroad, particularly to the West, and seeking foreign appreciation and linkage has become a goal and ambition of life. By and large, the new generation, particularly those with better opportunities in life, are neither adequately informed nor influenced by larger national fervour and interest as it used to be before. This in brief is our national milieu, and our scientists too belong to it.

While examining our performance in scientific research, it is also appropriate to bear in mind the kinds of inputs that are essential for quality research. The needed inputs may be categorized broadly into two groups: (i) Physical resources, and (ii) Non-physical resources. Physical resources include infrastructure, equipment, civil works, responsive management and administration, funds for operating and maintaining the activities, travel, etc. Non-physical resources include people with enquiring minds and creative abilities, intense motivation for scientific enquiry and a determination and willingness to stay with the problem despite distractions and difficulties, honesty of purpose and objectivity to deal

with scientific matters and peers in the field. We may also include under this head the need for an environment conducive to criticism, questioning, logical thinking, promotion of good work and of young scientists and in short an environment where scientific temper and culture prevail. While physical resources can be easily quantified and evaluated as to their adequacy, the non-physical inputs are abstract and hard to quantify; at the same time, they are crucial for quality research.

In this report, we shall be mainly discussing aspects related to scientific research with emphasis on basic sciences. Although technology cannot in principle be separated from science, the comments, criticisms and suggestions which follow pertain more to science than to technology, because these are the topics that were covered in the present Workshop. At the same time, it is fully recognized that the health of technology in the country has an important bearing not only on the health of science, but also on numerous national development activities. Perhaps the Academy will be able to give due consideration to this matter in the future. In science what is obvious is that the technology gap is a serious constraint for experimental research.

HEALTHY STATES AND TRENDS

Since we hear many unfavourable comments and criticisms about science in India these days, we should not be carried away with the impression that everything is wrong with our science, scientists and scientific research.

While adducing evidence for major accomplishments after Independence, it is now customary with good reasons to point out the successes in agriculture, atomic energy, space, power, oil exploration, etc. These are tasks accomplished for which anyone from a developing country like ours can take due pride. Bearing in mind the national milieu in which we work, these achievements become all the more creditable.

Since the main objective of this Workshop was to identify lacunae, weak points and handicaps and to suggest ways and means of improving matters, not much time was spent on highlighting our achievements and strengths. Notwithstanding this, it is important to set matters in their right perspective, so that we can retain the right balance in our judgement and suggestions. In what follows in this chapter, representative successes and healthy trends are considered briefly. They should not be considered as exhaustive.

(i) Scientific manpower as a national asset

It is often stated on the basis of statistics that we have the third largest pool of scientists in the world. According to some, this does not truly reflect the strength of science in India, because the bulk of these people are science graduates who contribute neither to the quantity nor to the quality of science. In the context of the present situation this is certainly true and we cannot ignore it. There is, of course, a positive side to it, too. The large body of young people trained at great cost and

effort are potentially a major national asset. They have had the basic training in the methods of science, have considerable awareness of science and familiarity with the language of science. What is needed is a radical change in strategy whereby their capabilities can be exploited for the promotion of the overall cause of science.

(ii) Facilities for science education and training in research

After Independence, the expansion of these facilities has occurred at an unprecedented pace and while on the whole the gains have been highly satisfying, there are certain points in respect of which corrective measures are called for. Thus, while a great measure of success has been achieved in the direction of modernizing syllabi, equipment and teaching and training methods at the postgraduate level, the fast rate of growth in itself has inevitably resulted in failure to impose standards uniformly at all levels. Consequently, even though in overall terms the qualitative and quantitative gains have shown an upward trend, the cumulative improvement has not been commensurate with the investments made. A point of great satisfaction is that a good number of graduates and postgraduates in science and technology of very high calibre and capability are being continuously turned out of some of the select institutions like IITs and some universities. Unfortunately, a sizeable fraction of these have gone abroad and have preferred to settle down there. And not all of those who decided to stay in the country could find proper placement and resource support for their talents to be exploited fully. At the same time, it is gratifying to note that since Independence a large number of our young scientists and engineers have found good opportunities in fields such as agriculture, atomic energy, space and the industrial sector and have made excellent contributions, the impact of which is easy to discern.

Until recently, effort had been concentrated mostly in setting up new departments and institutions and increasing

the numbers and quantity. Our system of monitoring the growth was neither vigilant nor strong enough. Rigid critical evaluation of the results was not possible during the period of rapid growth. In a way this is not totally unexpected when we remember the national milieu in which all this is taking place. But in the final analysis, two encouraging things become evident. Firstly, the base in science and scientific research has improved significantly and has got strengthened over the last three decades, and secondly the atmosphere for critical appraisal of drawbacks and the constructive responsiveness to such criticisms and suggestions is now more favourable and receptive. This is evident from the stress given by the funding agencies to the constitution of peer groups to discuss and formulate thrust areas in science and engineering and to monitor and evaluate projects and programmes in progress. From the functioning of these groups one cannot fail to notice the improving objectivity and consideration for quality that are slowly getting injected into the system. All this again demonstrates that the gradients are positive and favourable for the emergence of better science in the future. Activities and decisions to consolidate these gains can accelerate the pace of quality improvement. We are better poised now to strike peaks of excellence than ever before.

(iii) Status of scientific equipment

For experimental research complex and sophisticated equipment has become a dire necessity. Gone are the days when one could carry out top class research with a shoe string budget and makeshift home made equipment. Except in some special fields, the general international trend is towards the development of more and more sophisticated instruments, often based on high technology. Since research is concerned with the very frontiers of knowledge, the equipment needed by scientists cannot always be bought. This underscores the need for a sound industrial base in the country. There are indications that our industry and technology are showing

gradual improvement in this respect. In recent years, a variety of equipment has been built by our industries for basic and applied research. Typical examples are: (1) Building indigenously the Variable Energy Accelerator by BARC at Calcutta; (ii) The giant remotely controlled antenna for radio astronomy for TIFR at Ooty; (iii) The 10 m steerable antenna for millimetre wave astronomy for RRI at Bangalore; (iv) the computer controlled 2.2 metre optical telescope for IIA at Kavalur; and (v) the automatic neutron scattering instruments at the research reactors CIRUS and DHRUVA. In Space Research and Nuclear Research even items like rocket motors, complete control systems and reactor vessels are now fabricated by the indigenous industry; and many other major items are either built inhouse or by the industry. It is certainly true that in high technology we are still lagging considerably, but the trends again are on the ascending mode.

(iv) Role of government

A healthy state of the highest importance for the promotion of science in any country and particularly in a developing country which we have in India in ample measure is the government support. While in many economically developed countries a good fraction of research support comes from private sources, in developing countries the main source of funds is the government. Furthermore, since science has now become a nationally organized activity, this factor assumes crucial importance. We in India are fortunate that the government's Science Policy and funding pattern have been continuous and enduring. All the central governments in power after 1947 have been patronising Science and Technology not only as instruments of national development but also for their intrinsic value to the humankind. Concrete examples of government's positive attitude in this regard are the facts that six central government departments are headed by scientists, there is a Member, Science, in the Planning

Commission, there is a Science Advisory Council to the Prime Minister, a Scientific Adviser to the Prime Minister and a Scientific Adviser to the Minister of Defence. This is a tremendous advantage which the scientists and technologists could and should make use of to achieve high levels of excellence.

INFRASTRUCTURE, INSTRUMENTS, FUNDING, MANAGEMENT, ETC.

(i) Physical resources

Physical resources for scientific research are certainly vital for doing internationally competitive science. The degree of competitiveness differs from field to field and in general international competition is the keenest in topics with the greatest intellectual challenge and highest application potential. Therefore, it is important that scientists working in such areas have the right physical resources at the right time. Among other things, the velocity of research (or the progress of research) also depends on the availability of physical resources. In India, it is a common practice to put the blame for the low velocity of research and low occurrence of peaks of excellence primarily on lack of physical resources. While this may be true in a sense, more often than not this aspect is overemphasised. In fact, it is also true that in many cases the existing infrastructure, particularly in major equipment and instruments, is not being optimally utilized. Though corrective steps for ensuring better management of the infrastructure are being introduced, the real change has to come through better traditions and greater appreciation of the problem by scientists themselves.

(ii) Infrastructural facilities

Infrastructure is an item in which university scientists have more cause for concern than those in national laboratories. Until recently funding agencies used to stipulate that grants given by them for research projects will not be available for improving or augmenting infrastructure. In the universities and the national laboratories necessary

infrastructure is expected to be fully provided by the parent institution. While in principle this sounds reasonable, the resulting real life situation has gone to the extent of erosion of even the basic needs for doing good science, particularly in the university system. While the state governments have by and large shown least concern for research in universities, the UGC with its limited funds has to meet the demands of all the universities more under democratic compulsions than with an eye for excellence and proper utilization of these funds. The result is that by and large, in the average university, the infrastructure is primitive and sometimes nearly absent. Reliable power, test equipment, essential and commonly needed laboratory instruments, clean and adequate space for research, airconditioning for precision instruments, minimum mechanical and electronic workshop facilities, administrative support, etc. without which no worthwhile research is possible in the modern era are not anywhere near adequate in these institutions. In recognition of this situation, DST has made perhaps the first move among funding agencies to relax this limitation to some extent and provide support for infrastructure in their research projects. It is hoped that infrastructure for research in universities will receive greater attention in the future.

(iii) Library facilities

Good library facilities, including research journals and books, are essential for the scientists to enable them to keep abreast of developments in the fields of their interest. However, with the proliferation of research journals and the steep rise in their prices even national laboratories are finding it difficult to subscribe to all journals, let alone universities which are often unable to subscribe even to the most important ones. In this connection it is encouraging to note that the Indian Institute of Science has started on an experimental basis a Current Awareness Service under which abstracts of current articles in physics are sent free to any research worker requesting for

them. More such services need to be started and working scientists with limited library facilities should take advantage of them increasingly. There is also vast scope for exchange of books and journals among libraries in metropolitan centres and even regions, and sharing of library facilities among research institutions, universities, etc. With more and more computerised informatic centres coming up in the country, the setting up of centralised data banks in science is becoming a distinct possibility.

(iv) Instrumentation facilities

Research instruments are becoming increasingly versatile, precise, automatic, complex and expensive. Many of the modern instruments have on-line computers executing numerous jobs. During the last decade or so, a revolution has been going on in the field of scientific instrumentation leaving our expertise to build competitive instruments way behind international standards. The result is that we are not paying adequate attention to the development of innovative instruments. The general policy is to buy computerised, automatic and expensive equipment from abroad. This brings in its wake two major handicaps for us: (i) efficient operation and maintenance of these instruments pose many difficulties, and (ii) we get them much later than scientists abroad, and they become obsolete quickly forcing us to continue to be dependent on imported equipment. These are very dangerous trends and if we do not take prompt action, this gap will keep on widening to the extent of becoming unbridgeable and we will be doing more of repetitive research rather than pioneering research. Some steps have already been taken to rectify the situation. A number of instrumentation centres, both regional and institutional, have been set up by DST and UGC. At these centres large pieces of equipment frequently needed by many groups are purchased from India and abroad and operated as a facility for the scientists of nearby research centres. Very little instrument development or building is

undertaken here. On the other hand, CSIR's Central Scientific Instruments Organisation at Chandigarh, BARC, DRDO and a few other national laboratories and public sector undertakings develop, innovate and fabricate scientific instruments. However, despite all these efforts, we are not able to meet even a small part of the total instrumentation needs of scientific research. Until about 20 years ago, scientists themselves used to build their own equipment; that possibility and culture have dwindled in many laboratories due to various constraints and the new international trends. All this calls for urgent action if we are to develop the capability to do research at the forefront of knowledge. The steps to be taken in this direction and other suggestions are given at the end of this chapter.

(v) Mode of research funding

The health of science depends to a great extent on the mode and level of funding done for it. In this respect we have much to feel happy about. The level of funding of scientific research has been going up continuously. And very often the constraint is not the lack of availability of funds but our capacity to absorb and utilise them effectively within stipulated time limits.

(vi) Management of research

Management of scientific institutions and scientists is an infrastructural aspect in respect of which there is need for improvement. Though in many ways scientific research is also an organised national activity like any other constructive activity, there are important differences which call for a management system which is more responsive to the goals, needs and methods of scientific research. Unlike in many other activities, here neither the goals nor the achievements can be qualified easily. Secondly, the risk factor for success is relatively high, being highest at the frontiers of science. Thirdly, there are always the possibilities of frequent mid-term

changes, closing down of unproductive programmes and starting of idea-based new projects. Further, scientific research has to be carried out under international competition and this entails urgency of preparatory actions like import of material and equipment and organization of infrastructure and facilities and these have to be done within stipulated time frames and very often the non-specialists fail to appreciate the urgency involved. Additionally, the methods and manner of working of active scientists differ significantly from those of other professionals. The scientist is usually preoccupied with his work and problems all the 24 hours of the day. He works in bursts and spells. He finds it difficult to keep to office hours. He would prefer to spend time with his researches in preference to routine administrative procedures of chasing files and people. The management system has to be responsive to all such needs. Presently, a majority of our research institutions are largely under the same kind of administrative and organizational control as any other institution. In a developing country like ours such control becomes stifling to the method of work and to the realisation of the goals of scientific research. We lack proper ability to handle autonomy and competence to manage science and scientific institutions. In the presently prevailing system of organized research, excellence in organization and management becomes almost a prerequisite for excellence in science. But all this is not to say that the scientist is not accountable, only the measures for accountability are different.

(vii) Role of peers

Peers have an important role in the management of science. Evaluation of the performance of individuals and institutions of science calls for adoption of objective methods by peers. Once this is done properly, there should be a willingness and mechanism for the individuals and the system to abide by the recommendations and act on them. This is absolutely essential to keep the activities dynamic and

internationally competitive. It should be possible to abandon mediocre programmes and start new ones of promise. In this we lack the will to take strong actions. Many review committee reports are collecting dust. In many cases, peer review system is either lacking or inadequate. New programmes continue to be launched allowing the old ones too to exist. This leads to mediocrity. Resources are spread thin and programmes decay below the critical level of efficiency in course of time. Even institutions which were once of high quality move towards this state in course of time. In matters of this kind, directors of laboratories and heads of institutions can play an all important role by formulating carefully prepared plans of action to introduce changes in steps and stages without resorting to shock treatment.

Suggestions and Recommendations

1. Infrastructure for research should be given the same importance as is given to research projects. Funding agencies should take a studied view of this aspect and take adequate steps to bring it to a minimum level of strength to support the scientist and his research. The areas of responsibility for providing infrastructure of the parent institution concerned, the UGC and the funding agencies must be clearly defined and demarcated. The host institution must ensure optimal and shared usage of the infrastructure.

2. In the universities and other institutions engaged in scientific research, all journals, periodicals, books and other relevant literature must be available to the scientists. Libraries and their methods of storing and accessing scientific publications must be modernized.

3. The Current Awareness Service of UGC under which the Indian Institute of Science supplies computer printouts of current abstracts of articles from journals free of charge to those who request for them should be extended to all scientific disciplines. It is high time to formulate a national policy in this respect.

4. Libraries must have efficient arrangements with other libraries in metropolitan centres and in the same region to exchange books and journals and to share their facilities.

5. A National Information Centre capable of catering to the information needs of the working scientists effectively should be set up without much delay.

6. Urgent steps need to be taken to formulate and implement a national policy on instrument development and fabrication. This should be treated as a matter of extreme urgency. It would be a healthy practice to earmark a portion of the budget (say 10-20%) of a scientific department of a university or national laboratory for maintenance and upkeep of the facilities and scientific instruments.

7. Funding agencies should encourage scientists to undertake innovative instrument development projects. Projects pertaining to the development of novel methods, new sensors, probes and detectors, etc., and improvement of the latest commercially available instruments must be funded liberally. And the parent institutions must extend to such scientists the same recognition and encouragement as is given to other scientists.

8. Routinely used laboratory instruments for research must be improved upon and produced in large numbers.

9. Regional instrument centres should be strengthened so that they can carry out R & D activities related to instrument development. Specific responsibilities for instrument development (in addition to operation and maintenance of sophisticated instruments) should be assigned to each centre with associated accountability.

10. A suitable mechanism should be evolved and introduced under which the major items of equipment available at national laboratories, universities and industry in different metropolitan centres and regions can be shared by research scientists in the concerned centre/region.

11. An understanding and methodology should be evolved on national basis for private and public sector industries to support scientific research in universities on a continuing basis.

12. The review system for assessing the performance of individual scientists as well as research institutions must be introduced wherever it is not operative so far. We must stop supporting and continuing third rate science. Once it is established that a project is of mediocre type, it must be abandoned. Proper follow up and implementation of reports of Review Committees should be ensured.

13. Research institutions, particularly those in the university system, must be provided with a responsive and sympathetic management system. UGC should evolve a suitable framework for it and introduce it wherever it is needed.

14. The positive and negative aspects of the centralised institutionalisation of science after 1947 should be evaluated thoroughly.

HIGHER EDUCATION AND SCIENTIFIC RESEARCH

The main sources of manpower for scientific research are the universities, IITs and other educational institutions imparting postgraduate education in science. No efforts towards improvement of the quality of our scientific research can succeed unless we ensure that the right young people in right numbers are inducted into the system and the methods of education and training in research are so modified that instead of the traditional approach of providing facilities for acquiring knowledge they are motivated into cultivating the spirit of enquiry and independent thinking. Our unsatisfactory performance in scientific research is also a reflection on the unsatisfactory performance of the educational system. The main components of the higher educational system are: the students, the teachers, the educational content, the examination system, the resources available from the funding organisations, and the management system. Much has been written and spoken about these matters during the last two years and a new national policy is supposed to be on the anvil. Therefore, the present report has been restricted to some of the salient points which were highlighted at the Workshop without much elaboration. Further, the present observations are limited to the M.Sc. and Ph.D. levels in science.

(i) Outmoded educational system

A general observation on our higher education will be appropriate at this place. At the time of Independence in 1947, we had about 25 universities, generally patterned on the British system. Since 1947, radical and rapid changes have taken place in science, and in science teaching and the examination system. Scientific knowledge has increased by

leaps and bounds; technology too has advanced tremendously. This called for radical changes in curricula and teaching methods. The examination methods too needed to be changed so that the emphasis was on testing the ability to think and innovate rather than to reproduce the information stored. Unfortunately, we concentrated more on mere physical expansion of the educational facilities. The much-needed readjustment of the educational system to the changing situation did not come up. It can be seen that many of our problems have arisen out of this lapse on our part.

(ii) Admission to postgraduate courses: Need for selectivity

It is an accepted fact that barring exceptions, admission to M.Sc. and Ph.D. courses is not sufficiently selective. A significant fraction of the students have neither the aptitude nor the motivation for science. This by itself is an important reason for the low average standard. Excellence requires selective promotion. At the M.Sc. level, an entrance examination should be compulsory and suitable questions and tests should be devised to assess the applicants in respect of their abilities, aptitudes and motivation for science. Only those who make the grade in this examination should be given admission to M.Sc. Attractive stipends should be given to a good fraction of the top students. At the Ph.D. level too, admission should be made much more selective. UGC and CSIR hold national examinations to select those students who have the right qualities for doing research; this entitles them to a research fellowship. But there is no check on students who join for Ph.D. with their own resources or with stipends from other sources. If this system of selective admission is followed uniformly all over the country, initially there will be a drop in the numbers admitted to M.Sc. and Ph.D., but there will be a positive improvement in the standards. Also, all of them are likely to find employment without difficulty after the completion of their studies. A proposal was also made at the Workshop that entrance tests carefully formulated to evaluate

the research aptitude and motivation for Ph.D. may be held when the students are in the first year of M.Sc.; this would possibly help to reduce the extent of brain drain and to enhance motivation.

(iii) Quality of teaching and research staff

Regarding teaching and research staff too, the average situation is far from satisfactory. A combination of many factors has been responsbile for a large number of undeserving scientists getting appointed into these cadres: Narrow local loyalties getting an upper hand in appointments; pressures and influences from politicians and officials; outright bribery; the systems of donations for private colleges; difficulty regarding mobility; and the generally poor abilities and talents of the applicants. Formation of unions and collective bargaining for promotions and privileges de-emphasizing merit have undermined the dignity of the profession and suppressed the motivation of the teachers to their primary tasks and responsibilities. While it is universally accepted that teachers at the M.Sc. level must also be engaged in research work, a sizeable fraction in India are not and hence are unable to share the excitement of new discoveries with the students; many of them are not endowed with the aptitude for research. Some other weaknesses and handicaps are: Lack of adequate and periodic orientation courses for teachers; lack of facilities to attend national seminars and symposia; neglect of ethical considerations; heavy teaching loads; and lack of healthy relations and easy communication between teachers and students. Another lacuna is the lack of proper linkages with national laboratories and other R & D laboratories.

(iv) Syllabi and teaching methods

There is also lot that is wanting in the syllabi and teaching methods at M.Sc. level and in the quality of research done. Science is moving at an ever accelerating pace. This means that the total knowledge is increasing fast and it is too

much to expect the students to learn and understand all of it. The teachers too require continuous retraining and familiarization courses. Laboratory work needs to be updated continuously. We must realise that hereafter we cannot teach all available knowledge on any given topic to students. Emphasis must, therefore, be on teaching them the fundamentals and helping them to solve problems and think for themselves critically, logically and creatively. Learning by cramming must be de-emphasized and learning by thinking encouraged. Tutorial colleges are playing havoc, the only motive for them being to enable the students to get higher and higher marks. In research too our weaknesses are many: Poorly qualified researchers and students undertaking research at sub-critical level, lack of infrastructure and resources, inbreeding, isolation, low level of motivation for students and teachers, and continuing research along beaten paths and sometimes foreign fashions, leading nowhere to new knowledge. Majority of the theses written for Ph.D. are worth near-nothing. And these students after Ph.D. become teachers in the same colleges and universities and continue research on the same problems. Of course, there are exceptions, but we are talking here about the overall situation in the country.

(v) Status of medical research

Some special remarks need to be made regarding postgraduate studies and research in medical science in the country. Medical science is making progress at an ever increasing pace all over the world. With new discoveries in biology and biochemistry and the availability of ever new and novel techniques, instruments and methods, medical science is already doing wonders and is poised to do much more. On the other hand, our efforts, investments and involvement match neither the international trends nor the national needs. The overall priorities in this area have to be fixed and steps taken to raise the level of medical research in the country. Research in all medical colleges must be made mandatory.

(vi) Outmoded examination system

The examination system has, during recent years, received the keenest criticism because of the all-consuming stress on getting high marks, the associated malpractices that have grown to disturbing levels and become all-pervading, and the falling standards. The examination system lays prime accent on cramming and reproducing what has been stored in the memory. There is no doubt in the minds of knowledgeable people that there has to be a major change in the system. A system that seems to work well and is based on continuous assessment, project work, problem solving and written examinations is in operation in IITs. The question, therefore, is why it cannot be introduced in the universities. With all this, the situation is still unchanged and seems beyond improvement in our universities so much so that many are talking about delinking degrees from jobs, hoping that this in turn will bring indirect persuasion on universities to introduce reforms in the examination system. Whether this step will have the desired impact on our education and employment systems is hard to predict at this stage.

It is well recognized that a majority of our universities suffer from lack of funds. This is more so in the case of universities under the control of state governments as against those under the central government's control. By and large, university funding and management are not given priority by the state governments. No other steps will help higher education and research in science if adequate funds and an organizational and administrative structure matching the academic demands are not provided.

Suggestions and Recommendations

1. All university departments and colleges which have postgraduate teaching in science must have research programmes, so that postgraduate teachers are involved in research.

2. Admissions to M.Sc. and Ph.D. courses should be purely on merit basis. In order to assess the abilities and inclinations for higher studies in science, suitable tests, oral and written, should be developed for evaluating their aptitudes, creativity, inquisitiveness of mind, comprehension, ability to communicate and face situations, etc.

3. Special efforts should be made to attract some of the best students to science. The following are among the steps recommended for this:

—Discovering talent at degree level and giving to the selected students special attention and encouragement;

—Instituting adequate number of merit scholarships and fellowships even at B.Sc. level and raising their values to a level sufficient to attract students with the right aptitude to research careers;

—Improving and strengthening student-teacher relations, essential for discovering talent and encouraging the initiative, motivation, self-confidence, etc., of the students;

—The best scientists in the department should teach undergraduate students and share with them the excitement of science, scientific methods and new knowledge.

4. Recruitment of teachers must be on merit only based on their ability to teach and do research.

5. As far as possible past students from the same university must not be appointed as teachers immediately on their getting the degrees. They must work for at least 2-3 years in other universities before they are considered for appointment in their own universities.

6. Teachers' participation in planning and execution of the work of postgraduate teaching, research and management must be increased.

7. Teaching methods should lay more emphasis on problem solving and in general aim at building up innovative

capabilities among students and developing in them the ability to face unexpected situations. Orientation courses should be organized for teachers for this purpose.

8. Linkages among universities, national laboratories and industry in major cities and regions should be established. To start with, a deliberate and organized beginning should be made in cities like Bombay, Bangalore and Delhi on an experimental basis. Such an endeavour is bound to be of tremendous value to the educational and research systems in the universities. A document defining the objectives and spelling out the steps to be taken should be prepared by a group of experts and educationists. The instruments, facilities and manpower in national laboratories and industry can be exploited to great advantage. The practice of making joint appointments in universities and national laboratories/industries should be tried out. An in-depth study of the existing linkages and steps for the future is warranted.

9. The culture of regular seminars by students and staff should be introduced in all institutions having postgraduate courses.

10. The modified educational system should have in-built provisions for easy mobility of students and research scientists. These provisions should cover such aspects as accommodation, monetary compensation for double establishments, system of sabbaticals within the country with leave pay and creating visiting professorships in universities and nationl laboratories.

11. An effort should be made to locate major national scientific facilities in or very near university campuses.

12. A Scientific Research Council should be set up by UGC to coordinate activities aimed at promoting and strengthening research in universities and colleges.

13. The working of the colleges to which autonomy was given by UGC must be reviewed, and if the experiment has

succeeded, more colleges should be given autonomy in a phased manner. Some of these colleges can develop into centres of excellence and models for emulation by others.

14. Study circles of small groups of M.Sc. students should be organized by each national laboratory at different places. This by itself will be a catalyst for motivating and training talented students. Academies and professional societies can also participate in this programme.

BRAIN DRAIN

Brain drain has been a subject of great concern in recent years. However, the concern on this matter is not shared in the same manner and to the same extent by all. One argument is that as long as there is a significant gradient between India and the developed countries academically and economically, there is bound to be a flow of talent outwards and that the most effective way of stopping it is to raise the academic and economic levels in India. While this may be a satisfactory explanation for the state of affairs, others argue that for a poor country like India where higher learning is state subsidised in a great measure, one cannot allow this to freely drain the country of some of its best talent year after year; something concrete has to be done about the matter. As an example of the magnitude of the problem they point out that from the five IITs which have succeeded in selecting and training students of the highest level of aptitudes and intellectual abilities, a few hundred of the best go abroad every year and it is going on unabated. A very low fraction of these return to India. It is revealing that in the annual Presidential Young Investigator Awards given by the National Science Foundation, USA, to 100 young engineers and scientists, there were eight Indians in 1985 and four in 1986. There is also another kind of movement of talent from science within the country. During the last decade or two, one is witnessing a rush of the best students towards management and administrative avenues, because they are more lucrative in terms of salaries, perks and power. However, this trend need not be considered as causing loss of talent.

Much talk and effort have gone into inducing and persuading those who have preferred to settle down abroad to

return. Many governmental and non-governmental delegations have toured foreign countries to meet such people and encourage them to return, offering them as attractive opportunities as possible. But by and large the success achieved so far has been negligible. A view is emerging now that we must not unduly worry about the return of qualified Indians from abroad.

There have also been attempts to enquire into the reasons for the migration of talent out of the country. Apart from the attraction of better academic and economic opportunities and a higher standard of living in advanced countries, one is able to identify many contributing factors, big and small, from the Indian side. Anyone seriously interested in scientific research always aims for the very best opportunities, particularly when one is young. In India, the infrastructure, facilities, instruments, etc., for scientific research, particularly in experimental sciences, do not measure up to those available abroad. Young people are quite aware of this fact and give this as an important reason for their migration. Opportunities for quality jobs for talented scientists too are very limited in India. Among the other causes which encourage our young people to go abroad are lack of adequate recognition for merit and achievements (in terms of awards, promotions, assignment of new responsibilities, etc.), administrative and managerial red-tapism needing the active scientist to waste time and effort just to chase papers or to get approvals, difficulties in establishing contacts with peers and international developments, meagre opportunities for intellectual stimulation, an insensitive, outmoded and unresponsive management system not geared to dealing with science and scientists.

It will take a long time to make conditions in India comparable to those obtaining in countries like USA. It would be in the fitness of things to set it as one of our major goals. In the meantime any step to induce our best talent to remain in the country and to attract back those who are abroad should receive immediate attention.

It is also important to remember that the bulk of our young people do stay in India and contribute their very best to the science in the country. Many of them, including the best, do this out of an intense feeling of nationalism, belonging and loyalty and disregarding many attractive opportunities and invitations to accept positions abroad. This needs to be acknowledged in all our discussions and actions and every effort should be made to improve the work environment for such persons.

Suggestions and Recommendations

The following steps are recommended to attract Indians abroad to return and then retain them here:

1. Indian embassies in developed countries should prepare directories of Indian scientists, engineers and technologists in the countries concerned with full information on their areas of specialisation, current work, achievements, etc. They should also keep in touch with them to the extent possible.

2. The embassies must also effectively disseminate information on new opportunities and policies in India to the concerned people.

3. When senior scientists, engineers and others concerned go abroad, they should meet these people and tell them about the possibilities back home and that they are wanted in India.

4. When appointments are made, bureaucratic procedures should be eliminated/simplified to the maximum extent possible.

5. The welfare of the family must receive attention, and help and goodwill should be offered to them so that they may settle in their new place of work and the transition is as smooth as possible. Often they encounter innumerable problems in this regard and the unresponsive nature of our system has driven many of them back.

6. The Scientists Pool in CSIR is a step in the right direction. But it requires changes to make it more attractive by offering better remuneration according to merit and immediate placement at the right institution.

7. A favourable work environment would induce many to return and stay on. For this, they should be assured of (a) stimulating work and opportunities; (b) their ready acceptance in the local system; (c) opportunities to go abroad for conferences and contacts periodically (e.g. sabbaticals and summer visits); and (d) reasonable salaries, benefits and perks without upsetting the balance with the local scientists.

8. Each IIT, university and national laboratory should maintain a register of students and young researchers who go abroad for higher studies or training and maintain their career record on year to year basis to the extent possible. If properly done, a sense of belonging can be established through this linkage.

A suggestion is often made that when a scientist or an engineer who has received special training in India wants to go abroad, there should be some governmental legislation or rule binding him to pay an adequate compensation to the country. Some think this to be an undesirable proposition. This aspect possibly needs detailed examination. Alternatively, it may be made obligatory for all those interested in going abroad to put in at least one year's national service in a suitable form.

NON-PHYSICAL RESOURCES

Scientific creativity thrives under a stimulating environment and requires personal qualities of individuals which are hard to define. This is the reason why people often refer to it as scientific temper and culture which is the sum total of all such non-physical resources and qualities as are essential for attaining excellence in science. In fact, there are important differences between creative science and creative arts. For example, creative music and painting are based on a variety of elements related to local traditions and style, though their beauty appeals to all when their quality is high. There are no defined international standards to measure their quality or international competitiveness. On the other hand, science is the same for all; it is not related only to local events and things but must be universal in its sway and applicability. It is mathematically rigorous and does not tolerate exceptions, subjective views or local opinion. But for all its abstractness, creativity is an essential ingredient for excellence in science. At the same time, we must remember that while science is universal, scientific method has to be related intimately to local problems whose solutions can be local-specific.

The aspects covered at the Workshop include: atmosphere conducive to creative science; motivation of the individual; interaction among peers for intellectual stimulation; and possible effects of socio-cultural factors on creative science.

(i) Environment for creative science

Creative science is an intellectual enterprise. It is, therefore, natural that the intellectual faculties have to be sharpened to cut, penetrate and pry open the most forbidding problems and situations. When dealing with the unknown, a

measure of speculation and conceptual ideas is also necessary. The mind has to be receptive and open for new thinking, and sharp enough to critically evaluate ideas, results and observations. These qualities flourish under an atmosphere of intellectual freedom. Ideas are often born out of discussions with peers. Intellectual constraints arising out of factors such as obedience to authority and seniority, fear of free expression, isolation from peers, dishonesty of purpose or means, destructive criticism and lack of appreciation of good work accomplished go to build an atmosphere which can be destructive for creative work. The opposite of these favour and promote excellence. With this background we may examine the state of affairs in the country in this respect.

Many of our traditions in society and government are based on the authority of the seniors and the hierarchy permeating downwards. The same philosophy is prevalent in science management too. In particular it is deeply entrenched in the university system. Frequently, the so-called seniors in the academic world try to cover up their mediocrity in science by resorting to imposition of their authority on the juniors, adding their own names as coauthors of papers of younger people, standing in the way of the appointment of talented people to the staff and in general suppressing merit. The atmosphere is thus vitiated.

It is well known that the most creative contributions in science come about when the person is young. In mathematics and highly conceptual theoretical sciences, particularly in physics, this is very evident and the upper age limit of real creativity is said to be about 35 years. The corresponding age for experimental sciences is somewhat higher. At this age they are still not well known, but their minds are in the most productive stage and they require to be encouraged and promoted. However, in many cases our system and individuals lend to them neither the opportunities nor the freedom and encouragement to help them to bring out their very best. In

this regard we have to make radical changes in our attitudes and value system to respond to the needs of creative science.

(ii) Motivation

While the environment provides the right atmosphere for scientists to carry out their researches, the individual's total personality provides the starting point. Science is essentially an individualistic endeavour. Here, apart from the native intelligence of the individual, the next most important factor is motivation. Creative work of any type requires an all-consuming passion and drive of the individual which impels him to give his very best. At times and in spells, the entire personality of the scientist is engrossed in the problem 24 hours of the day until it almost hurts. What such motivation does is to mobilise every little talent of the individual—memory, imagination, adventurism, flight of fancy, foresight, logic, rationality, pragmatism, patience, perseverence, etc.—to bear upon the problem for finding a solution. In addition, the mind has to be free from worries and mundane problems.

What brings about such motivation? We may not have a clear answer for this question, but there are many contributory factors. In history, men like Galileo, Newton, Einstein and Raman had an extraordinarily intense and intrinsic urge for inquiry into nature. This drove them unceasingly to their achievements. But in the present day situation of organized science there are many other factors too. An intense competitive spirit, a drive to be the greatest person in one's field of activity, a strong nationalistic motive and national pride (science may be international, but motive may be national, e.g. the urge to put the country on top of the world) and such like qualities combined with others can provide the needed motivation.

In our country, a young scientist is often burdened with many extraneous cares and worries that tend to suppress his motivation for science. The atmosphere and system too are not

responsive to the strongly motivated. Consequently, both the young and the old operate at a low level of their potential peak power all through their lives.

(iii) Effect of socio-cultural factors on creative science

We have seen that the present Indian socio-cultural milieu has many distractions which hamper our progress. A pertinent question is: Do some of them hinder excellence in science? There is lot of superstition and irrationality among many of our people. On the face of it we are inclined to infer that such qualities are contrary to the method of science. But there are instances where people of very superstitious nature have done quite outstanding science. Another belief quite prevalent among us is fatalism. Fatalistic attitude is quick to accept defeat and thus erodes perseverence. Would fatalism inhibit the drive to attain success in spite of many defeats?

Science thrives on a questioning mind. But our family, social and educational systems are based on unquestioned obedience to authority and seniority. Questions and arguments are considered to be expressions of an impertinent child. Does this affect our ability and attitude to achieve quality science? Again in our value system in the family, in school and college, and in society at large, there is a large premium on anything foreign. To what extent does this drive the young to go abroad and not return?

Thus, we see that there are individual opinions and inferences about whether our socio-cultural milieu affects our performance in science, but there are no learned views on this issue based on systematic studies.

Suggestions and Recommendations

The non-physical resources considered above have much to do with the attitudes of scientists both individually and collectively. The action points, therefore, centre around scientists as well as scientific academies and professional bodies. We have three national science academies, a large

number of state academies and numerous science societies and associations. All of them can contribute in this direction.

1. Every individual scientist must be a party to a code of conduct which should include guidelines for his own style of work as well as his interaction with his colleagues, young and old. Such a code of conduct should be evolved by the various bodies responsible for promoting science in India. The scientists must then be informed about it, participate in discussions on it and finally become willing partners in its implementation.

2. Every working scientist should willingly contribute to the creation of an atmosphere in his institution which is conducive to free and constructive interaction among scientists.

3. Ph.D. students and young scientists should receive special attention and favourable treatment from older scientists. Everything should be done to encourage their initiative and leadership qualities in doing science. They should be periodically given either an independent investigation or primary responsibility for a major task in a large project, so that their potential can be converted into achievement. They should receive encouragement through merit promotions, involvement in planning, liberal permission to attend national seminars and workshops, deputation to attend international conferences, sympathetic consideration of proposals for new experiments, etc.

4. Scientists from different departments of a university or institution should sit together and review their researches periodically. They should jointly agree to the winding up of less productive programmes, to the starting of new idea-based experiments and strengthening of existing programmes with greater potential.

5. Joint discussions among scientists in the group whether for evaluating the results of a project, formulating long term

plans, or matters of common interest should be held in an atmosphere of objectivity and cordiality.

6. Regular weekly seminars of all members of the group should be held for discussing preliminary results of work in progress, reviewing exciting work underway in other research centres and reviewing the state-of-art of the field as a whole.

7. Joint studies involving natural scientists and social scientists aimed at investigating in the Indian context, the impact of various socio-cultural-economic factors on the endeavours at achieving excellence in science should be carried out.

8. In most institutions there is a tendency to take on far too many individual investigations rather than concentrating on a limited number of thrust areas. This pattern must be consciously altered through discussions among concerned scientists.

9. Even within the present management system, directors and heads of laboratories can bring about substantial changes for the better. For this they have to be firstly sure about the appropriateness and need for those changes and then take bold decisions.

10. Scientists have the responsibility as well as the scope to contribute towards science popularisation and mass education in science. Mass media should be fully exploited in an organized manner for this. The science academies, scientific professional bodies, science associations and individuals should play a meaningful role in this direction.

NEW INTERNATIONAL TRENDS IN SCIENCE

With the rapid growth of science during the 20th century, particularly the acceleration in the rate of growth that has taken place after the 2nd World War, certain new trends have emerged. It is necessary that we take note of these and take suitable long-term steps, so that we are not left in a position of disadvantage in the years to come.

(i) Currently, a major revolution in science is sweeping the world. The future is in the hands of science. There are clear indications of this from the discoveries in biology (at all levels), biotechnology, electronics, computers, space, materials science, sub-atomic physics and astronomy. If we are full participants in this march of science today we shall reap full benefits from it tomorrow. Let us take serious note of this reality.

(ii) Science is becoming increasingly big, calling for more and more of teamwork. In India, we are yet to learn to work in large teams with a spirit of cooperation and understanding. Though it was not the normal way of working in science in earlier years it is now becoming necessary to compete with the other countries of the world. In certain fields like sub-atomic physics, a single experiment may have the participation of 100 or more scientists from several countries. In fact, some Indian groups are already participating in some of these experiments. We have to carefully weigh the pros and cons in joining such programmes from all points of view for the future. These are collaborations not only among many groups within the country but among groups from many countries too.

(iii) Interdisciplinary science is paying increasing dividends. This involves working together of scientists from different

disciplines. In India where we often work in water-tight compartments, we have to make conscious efforts to break these barriers and bring the scientists from different areas to work in unison on the same problem.

(iv) More and more of basic science with high application potential is carried out by the industry all over the world. This has many advantages. Provision of greater resources, physical and human, is possible in projects sponsored by industry, because they are result-oriented. Concentration of effort and resources is also easier. And when major findings are made, there are no hindrances to rapid exploitation. In India, hardly any research worth the name is sponsored by industry on these lines. It is high time something concrete is done in this direction.

EPILOGUE

At the outset it is important to state that while organizing this Workshop there was a full realisation about the close connections between science and technology and of the fact that the health of one affects that of the other in a big way. Notwithstanding this, because of the diverse dimensions of the problem and a desire to have an in-depth discussion with a relatively small group of specialists, the scope of the Workshop was limited to the subject of the health of science. Even here, not all topics could be covered because of various constraints.

Recognising that many meetings on similar topics have been organized in the past, INSA had set for the Workshop the important objective of identifying the causes for the poor health of science in the country and making specific pragmatic recommendations for remedying the situation. In this we have succeeded to a great extent and several suggestions and recommendations worthy of serious consideration have been listed at the end of each section.

In the course of this Workshop, we have faced on repeated occasions the need for factual and reliable information and data on various facets of science education, training, research, manpower, resources, etc. In the absence of such data there is a tendency to make generalisations on the basis of the meagre information available. In this there is considerable room for personal biases to creep in. It is, therefore, essential that such reports are prepared with care as urgently as possible. This is needed in some cases if meaningful corrective steps are to be taken.

ANNEXURE 1

List of persons who submitted papers on the various topics covered in the Workshop

1. T. N. Ananthakrishnan, Madras
2. Ashok Ghosh, University of Calcutta, Calcutta
3. B. K. Bachhawat, University of Delhi, Delhi
4. N. Balakrishnan Nair, University of Kerala, Trivandrum
5. V. G. Bhide, Poona University, Pune
6. B. B. Biswas, Bose Institute, Calcutta
7. D. P. Burma, Banaras Hindu University, Varanasi
8. B. Buti, Physical Research Laboratory, Ahmedabad
9. R. Chidambaram, Bhabha Atomic Research Centre, Bombay
10. V. L. Chopra, Indian Agricultural Research Institute, New Delhi
11. R. R. Daniel, Tata Institute of Fundamental Research, Bombay
12. M. G. Deo, Cancer Research Institute, Bombay
13. A. S. Ganguly, Hindustan Lever Ltd, Bombay
14. V. K. Gaur, National Geophysical Research Institute, Hyderabad
15. P. J. Lavakare, Department of Science & Technology, Delhi
16. R. A. Mashelkar, National Chemical Laboratory, Pune
17. J. V. Narlikar, Tata Institute of Fundamental Research, Bombay
18. Nitya Anand, Central Drug Research Institute, Lucknow
19. K. R. Parthasarathy, Indian Statistical Institute, Delhi
20. D. Shankar Narayan, Bangalore University, Bangalore
21. B. V. Sreekantan, Tata Institute of Fundamental Research, Bombay

22. Surajit C. Sinha
23. B. M. Udgaonkar, Tata Institute of Fundamental Research, Bombay

Rapporteurs for the Workshop

R. R. Daniel
S. K. Joshi
H. Y. Mohan Ram
P. N. Tandon